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EDITORIAL

Evolving generation of new Extended Depth of Focus intraocular lenses

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Functional vision is crucial in ophthalmology, especially in areas such as cataract surgery. Our lives have significantly changed, and technology has progressed rapidly over the past 3–4 decades with the advancement of computers and mobile phones/screen-based devices, which are increasingly used in all modes of life compared to non-screen based tasks previously performed. According to the report by the ESCRS functional vision working group, 55 years and older Europeans spend at least 6 h per day on leisure activities, including playing games and computer use, relaxing/thinking, reading, watching television, socializing and communicating, participating in sports, exercise, and recreation, and other activities including travel [1]. Similarly, in the United States, the proportion of time spent on leisure and sports activities ranges from 23% of daily time (i.e., 5.5 h) for individuals 55–65 years to 32% (i.e, 7.7 h) for individuals >75 years of age [1]. Besides leisure activities, several working distances are also needed for performing other everyday tasks, such as cooking, seeing the speedometer in a car, or walking on uneven ground [1–3]. Therefore, the definition of functional vision as just improving the distance vision many decades ago has changed to have good distance and intermediate vision to enable the patients to do their daily tasks on day-to-day technological gadgets.

Today, we have a wide range of intraocular lenses (IOLs) that cater to distance, intermediate, and near vision needs, wholly or partially. The first trifocal IOL was introduced in 2010 [4], extended depth of focus (EDOF) IOLs in 2014 [5], and monofocal IOLs with enhanced depth of focus were granted the first Conformité Européenne mark in 2019 [6–10]. There has been a lot of debate in the literature about the classification and nomenclature of the new enhanced monofocal and EDOF IOLs. In a recent paper by Fernandez et al., there was a suggestion to use the term extended depth of 'field' instead of 'focus' as 'field' represents the functional measure through defocus curves [10]. The corresponding terminology from the optical point of view is "through-focus response" [10, 11]. However, no universally agreed standards for classifying these modern lenses exist. Although the arguments about the nomenclature of the IOLs are scientific, for the non-academic surgeon, these classifications can be overwhelming. To maintain simplicity of understanding, I will use the term EDOF in this editorial to extend the depth of focus/field IOLs.

The monofocal IOLs are evolving to enhanced monofocal IOLs [8, 12] to provide functional intermediate vision and EDOF IOLs cater to the full intermediate vision requirement [13] and functional near vision. At the same time, bifocals and trifocals cater for distance + near and distance + intermediate + near visions, respectively. When it comes to distinguishing the monofocals from enhanced monofocals and EDOFs, there is more than one parameter which can be used [e.g., patient's subjective outcomes of intermediate vision gain, objective measurement of intermediate vision, following a particular classification of IOL, ANSI (American National Standards Institute) standards etc.]. However, a clinician's basic understanding of the defocus curve will give them some idea of the 'optimal' performance of an IOL when they are introduced to a new IOL technology. In a very brief and lay term and for ease of remembrance, a very simplistic understanding of the defocus curve of monofocal, enhanced monofocal, EDOF and trifocal IOLs can be seen in Fig. 1. However, it must be noted that some of the IOLs will fall between these categories, providing a slightly different visual outcome and defocus curve. Moreover, based on how the lenses are classified, some trifocals may not be dis-similar to EDOFs and vice versa [10]. The knowledge of the defocus curves of these IOLs can be instrumental in offering spectacle independence when some mini-monovision is targeted.

To test any new EDOF IOL, it is essential to show its outcomes on bench studies first and then to show that the clinical outcomes mimic the bench study outcomes. In addition, it is imperative to compare the clinical outcomes of the new EDOF IOL to those of the existing enhanced monofocal and diffractive EDOF IOLs. In this supplementary issue there are three articles on the new purely refractive EDOF IOL, TECNIS PureSee™ (ZEN00V) by Johnson & Johnson Vision, Jacksonville, USA. The first article by Alarcon et al. [14]. focuses on the optical bench analysis of TECNIS PureSee™ IOL. It shows that this new IOL provides a similar visual range as the diffractive EDOF IOL TECNIS Symfony™, but with a better dysphotopsia profile which is comparable to a monofocal IOL. In the second article of this supplement, Corbett et al. corroborates the findings from the in vitro optical bench data in a multicentric randomized clinical trial where TECNIS PureSee™ was compared to the enhanced monofocal, TECNIS Eyhance™, showing similar dysphotopsia profile between both IOLs and statistically better intermediate and near vision performance of the new EDOF IOL [15].

The third article of this supplement by Black et al. [16], highlights the importance of tolerance to refractive errors (TRE). Currently, there is no standardized method established to evaluate and quantify TRE of IOLs. This paper addresses both preclinical and clinical metrics related to demonstration of TRE in the TECNIS PureSee™ IOL. Multifocal IOLs offer the most promising treatment near vision option for presbyopic patients [17]. However, they seem more sensitive to residual refractive errors, which can lead to patient dissatisfaction [18, 19]. Minimum postoperative refractive error is required to achieve optimal visual outcomes, with even minor astigmatism significantly undermining the patients' postoperative visual acuity [19]. However, residual refractive errors can be related to various factors, and it is impossible to predict absolute postoperative refractive errors. Refractive errors must be corrected as much as possible to fully exploit the benefits of multifocal IOLs [20]. The estimated percentage of enhancement procedures performed to reduce

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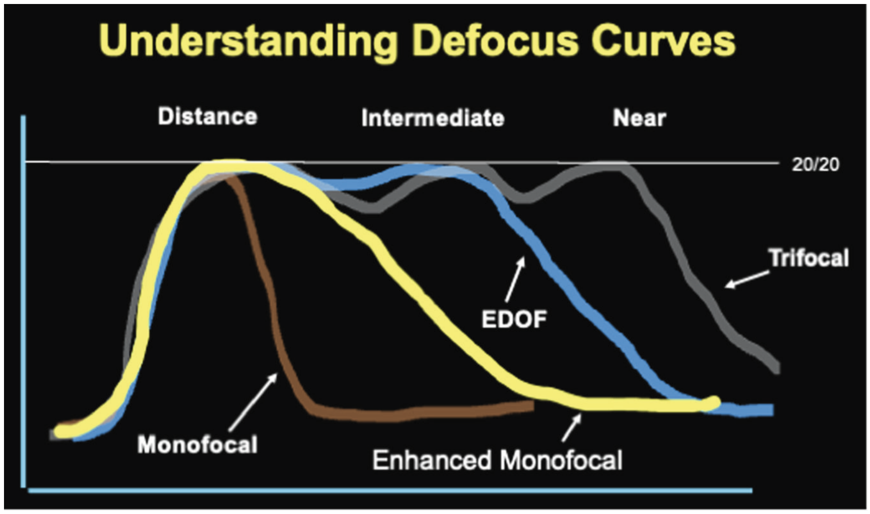

Fig. 1 Simplistic understanding of defocus curves. This figure is just for illustration and it does not represent any particular intraocular lens/es currently in the market.

residual astigmatism after implantation of multifocal lenses varies from 5.24 to 23.66%, depending on the study. For example, Gundersen et al. [21] observed considerable retreatment rates (10.8%) due to decreased visual acuity secondary to residual astigmatism. An EDOF IOL provides a significantly increased range of vision with minimal optical side effects of multifocality [22, 23]. The studies by Alarcon et al. [14] and Black et al. [16] in this supplementary issue show that the new purely refractive EDOF IOL, TECNIS PureSee™ (ZEN00V), provides good tolerance to small residual refractive errors on bench and clinical studies and is comparable to enhanced monofocal IOL on the same TECNIS® platform.

In summary, it was already known that around 9–10% of pseudophakic eyes with conventional aspheric monofocal will achieve good unaided distance and near vision, but the predictability of this pseudoaccommodation remains an issue [24, 25]. Enhanced monofocals provide a marginal improvement in intermediate vision performance compared to conventional monofocals [8] and EDOF provides good distance and intermediate vision with functional near vision [13]. Diffractive bifocals and trifocals provide predictable good distance and near vision, but dysphotopsia remains an issue. The new refractive EDOF IOLs seem promising technology for achieving predictable distance and intermediate vision with reasonable near vision [14–16]. and photic phenomenal similar to conventional monofocals. Thus, the quest to improve the quality of predictable vision for our pseudophakic patients continues.

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REFERENCES

1. Ribeiro F, Cochener B, Kohnen T, Mencucci R, Katz G, Lundstrom M, et al. Definition and clinical relevance of the concept of functional vision in cataract surgery ESCRS Position Statement on Intermediate Vision: ESCRS Functional Vision Working Group. J Cataract Refract Surg. 2020;46:S1–3.
2. Elliott DB, Hotchkiss J, Scally AJ, Foster R, Buckley JG. Intermediate addition multifocals provide safe stair ambulation with adequate 'short-term' reading. Ophthalmic Physiol Opt. 2016;36:60–8.
3. Rocha KM. Extended Depth of Focus IOLs: The Next Chapter in Refractive Technology? J Refract Surg. 2017;33:146–9.
4. Sudhir RR, Dey A, Bhattacharrya S, Bahulayan A. AcrySof IQ PanOptix Intraocular Lens Versus Extended Depth of Focus Intraocular Lens and Trifocal Intraocular Lens: A Clinical Overview. Asia Pac J Ophthalmol. 2019;8:335–49.
5. Kanclerz P, Toto F, Grzybowski A, Alio JL. Extended Depth-of-Field Intraocular Lenses: An Update. Asia Pac J Ophthalmol. 2020;9:194–202.
6. Fernandez J, Rocha-de-Lossada C, Zamorano-Martin F, Rodriguez-Calvo-de-Mora M, Rodriguez-Vallejo M. Positioning of enhanced monofocal intraocular lenses between conventional monofocal and extended depth of focus lenses: a scoping review. BMC Ophthalmol. 2023;23:101.
7. Mencucci R, Cennamo M, Venturi D, Vignapiano R, Favuzza E. Visual outcome, optical quality, and patient satisfaction with a new monofocal IOL, enhanced for intermediate vision: preliminary results. J Cataract Refract Surg. 2020;46:378–87.
8. Nanavaty MA, Ashena Z, Gallagher S, Borkum S, Frattaroli P, Barbon E. Visual Acuity, Wavefront Aberrations, and Defocus Curves With an Enhanced Monofocal and a Monofocal Intraocular Lens: A Prospective, Randomized Study. J Refract Surg. 2022;38:10–20.
9. Rampat R, Gatinel D. Multifocal and Extended Depth-of-Focus Intraocular Lenses in 2020. Ophthalmology. 2021;128:e164–85.
10. Fernandez J, Ribeiro F, Rocha-de-Lossada C, Rodriguez-Vallejo M. Functional Classification of Intraocular Lenses Based on Defocus Curves: A Scoping Review and Cluster Analysis. J Refract Surg. 2024;40:e108–16.
11. Remon L, Arias A, Calatayud A, Furlan WD, Monsoriu JA. Through-focus response of multifocal intraocular lenses evaluated with a spatial light modulator. Appl Opt. 2012;51:8594–8.
12. Giglio R, Vinciguerra AL, Presotto M, Jonak K, Rejdak R, Toro MD, et al. Visual outcomes and patient satisfaction after bilateral implantation of an enhanced monofocal intraocular lens: a single-masked prospective randomized study. Int Ophthalmol. 2024;44:112.
13. Son HS, Kim SH, Auffarth GU, Choi CY. Prospective comparative study of tolerance to refractive errors after implantation of extended depth of focus and monofocal intraocular lenses with identical aspheric platform in Korean population. BMC Ophthalmol. 2019;19:187.
14. Alarcon A, Del Aguila Carrasco A, Gounou F, Webber H, Piers P. Optical and clinical simulated performance of a new refractive extended depth of focus intraocular lens. Eye. 2024. https://doi.org/10.1038/s41433-024-03041-0. In this issue.
15. Corbett D, Black D, Roberts TV, Cronin B, Gunn D, Bala C, et al. Quality of vision clinical outcomes for a new fully-refractive extended depth of focus Intraocular Lens. Eye. 2024. https://doi.org/10.1038/s41433-024-03039-8. In this issue.
16. Black D, Bala C, Heredia AA, Vilupuru S. Tolerance to refractive error with a 1 new extended depth of focus intraocular lens. Eye. 2024. https://doi.org/10.1038/s41433-024-03040-1. In this issue.
17. Charman WN. Developments in the correction of presbyopia II: surgical approaches. Ophthalmic Physiol Opt. 2014;34:397–426.
18. de Vries NE, Webers CA, Touwslager WR, Bauer NJ, de Brabander J, Berendschot TT, et al. Dissatisfaction after implantation of multifocal intraocular lenses. J Cataract Refract Surg. 2011;37:859–65.
19. Macsai MS, Fontes BM. Refractive enhancement following presbyopia-correcting intraocular lens implantation. Curr Opin Ophthalmol. 2008;19:18–21.

20. Abdelghany AA, Alio JL. Surgical options for correction of refractive error following cataract surgery. Eye Vis. 2014;1:2.
21. Gundersen KG, Makari S, Ostenstad S, Potvin R. Retreatments after multifocal intraocular lens implantation: an analysis. Clin Ophthalmol. 2016;10:365–71.
22. Artal P, Manzanera S, Piers P, Weeber H. Visual effect of the combined correction of spherical and longitudinal chromatic aberrations. Opt Express. 2010;18:1637–48.
23. Lopez-Gil N, Montes-Mico R. New intraocular lens for achromatizing the human eye. J Cataract Refract Surg. 2007;33:1296–302.
24. Nanavaty MA, Mukhija R, Ashena Z, Bunce C, Spalton DJ. Incidence and factors for pseudoaccommodation after monofocal lens implantation: the Monofocal Extended Range of Vision study. J Cataract Refract Surg. 2023;49:1229–35.
25. Nanavaty MA, Vasavada AR, Patel AS, Raj SM, Desai TH. Analysis of patients with good uncorrected distance and near vision after monofocal intraocular lens implantation. J Cataract Refract Surg. 2006;32:1091–7.

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